

REMARKS

This Preliminary Amendment cancels the original claims, without prejudice, in the underlying PCT Application No. PCT/EP2004/052866. The Preliminary Amendment also adds new claims 11-20. The new claims conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.125(b), the Substitute Specification (including the Abstract) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to United States Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. §§ 1.121(b)(3)(ii) and 1.125(c), a Marked-Up Version of the Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) are respectfully requested.

The underlying PCT Application No. PCT/EP2004/052866 includes an International Search Report, dated February 11, 2005, a copy of which is submitted herewith.

Applicant asserts that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully submitted,

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6/16/06

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[10191/4792]

RADAR SENSOR AND METHOD FOR ITS OPERATION

Background Information *Field Of The Invention*

The present invention is based on a radar sensor ~~having the generic features of Claim 1.~~

Background Information

Current long range radar sensors for detecting objects using radar are designed to detect
5 targets at distances of up to 150 meters. For this purpose, highly focusing antennas must be
used, which e.g. according to the laws of optics emit the high-frequency energy into a narrow
space region using a focusing lens and, following the reflection by objects, receive it again
only from this narrow space region. The azimuthal locating field of current radar sensors
amounts to about plus/minus four to plus/minus eight degrees. In addition there are also radar
10 sensors whose antenna characteristic over an azimuthal angle is increased by swiveling the
antenna itself. Outside of the azimuthal angular range, within which the antenna is able to
transmit and receive, no targets are detected. Transmitting capacity, locating field, signal
generation, modulation and information evaluation are implemented in a fixed manner and
are not variable. Particularly disadvantageous is the fact that the sensor characteristic cannot
15 be adjusted while a vehicle is in operation.

~~Therefore, it is the objective~~ Summary Of The Invention

It is an object of the present invention to provide a radar sensor and a method for operating
the radar sensor which avoid the above-mentioned disadvantages.

~~Summary of the Invention~~ This problem is solved by a radar sensor according to Claim 1 and
20 a method for controlling the transmitting and receiving parameters of a radar sensor
~~according to Claim 4.~~ The radar sensor according to the present invention for a motor vehicle
having a transmitting device and a receiving device provides for transmitting parameters of
the transmitting devices and receiving parameters of the receiving device to be variable. This
variation, or adaptation, is to be controlled by certain events, situations or as a function of a
25 function selected by the driver. The selected function, for example, may be a driver assistance
function such as a parking assistance, an aid to starting from rest or the like. This allows for
an adaptive adjustment of the locating field of a radar sensor and its resolution with respect to
targets to be detected in their respective lateral positions, i.e. a distance and in an angular

position as well as with respect to the relative speed. Resolution in this context means the ability to distinguish between individual targets.

A further development of the radar sensor according to the present invention provides for the transmitting parameters to be the transmitting frequency and/or the transmitting capacity and/or the modulation amplitude and/or the azimuthal width of the emitted field. A further development additionally provides for the receiving parameters to be the receiving frequency and/or the receiving sensitivity and/or the azimuthal width of the received field. The adaptation or configuration allows for such a sensor to be used in a very universal manner for tasks of the short-range sensor system in the range of 0-14 meters at a very wide azimuthal coverage of e.g. plus/minus 50 degrees as well as for tasks at medium ranges up to 40 meters and an azimuthal coverage of plus/minus 20 degrees as well as for long-range detection above a range of 40 meters at an azimuthal coverage of plus/minus 8 degrees. The adaptation of the sensor occurs both by changing the azimuthal width of the locating field as well as in relation to the respectively required distance and speed resolution. Distance resolution ensures that as the distance between the targets and the sensor decreases the resolution always becomes more precise. In the short range of the vehicle, distance resolutions in the centimeter range are required, while in the long range a resolution of approximately only one meter is required.

The method according to the present invention for controlling the transmitting and receiving parameters of a radar sensor provides for transmitting parameters and/or receiving parameters to be changed as a function of the driving condition of the vehicle. The change of the transmitting and receiving parameters may concern the antenna itself or the generation of the transmitting signal or the processing of the received signal on an analog or digital basis. The driving condition is the speed, the direction, the location as well as the execution of possible special functions such as, for example, an aid to starting from rest or the like. Preferably at least the speed and/or an assistance function selected by the driver and/or the position of the vehicle and/or the installation location of the radar sensor in the vehicle enter into the driving condition. A further development of the method provides for the speed resolution of the radar sensor to be changed. This may be done e.g. by increasing the observation time in the form of an adaptive elongation of a frequency ramp in the FMCW method or by increasing the sampling rate in the case of a pulse radar.

A further development of the method according to the present invention provides for the distance resolution of the radar sensor to be changed. This may be done e.g. by a resolution increase in the short range by increasing the frequency deviation in an FMCW radar or by a variation of the pulse length in a pulse radar.

A further development of the method according to the present invention provides for the width and shape of the antenna characteristic to be changed. This may be done by switching the elements at the high-frequency level or by digital processing in the baseband, for example in the form of digital beam shaping by complex-valued weighting of the baseband signals of individual antenna slots.

A universally usable radar sensor that works adaptively in accordance with the present invention allows for the vehicle surroundings to be sensed both in the short range and up to the long range and thus allows for a vehicle detection up to 150 meters. For achieving the objectives of the panoramic radar view, this requires only one sensor architecture in a unified technology such that the economy of a panoramic view sensor system can be maximized. The advantage of the present invention lies in the fact that the configuration or adaptation of the sensor may occur as a function of certain vehicle situations or of functions selected by the driver. The frontend is suitably implemented in 77 GHz technology or at even higher frequencies.

~~An exemplary embodiment of the present invention is explained in more detail in the following description.~~

Detailed Description

The sensing of the vehicle surroundings fundamentally depends on the situation of the vehicle. The vehicle's own speed, position, direction of travel, the way in which the surroundings of the vehicle are interpreted or which special function, for example driver assistance functions, the driver has currently selected enter into the driving condition of the vehicle. If the vehicle's own speed, for example, is lower than 50 km/h, for example, then it is not necessary for a sensor to detect targets at 150 meters since these are then irrelevant for a cruise control. Instead it makes more sense in this driving condition to prioritize the detection of the short and medium range since events in this range directly affect the control behavior. For example, in an urban area on a three-lane roadway there could be at a medium distance (e.g. 30 meters) two vehicles on the two outer driving lanes, while the middle driving lane, on which one's own vehicle is located, is free. Then the monitoring of the two preceding vehicles is to be prioritized in order to ensure an optimum control of the longitudinal guidance e.g. if one of the vehicles swings into the lane of the host vehicle. The two targets would therefore have to be categorized as "especially relevant", and the detection probability may be maximized by adapting the sensor properties to these targets in that e.g. the antenna characteristic is more frequently reshaped to these targets. In this respect, the modulation method is adapted in such a way that the parameters to be assigned to the two targets, that is, distance, relative speed, lateral position, can be detected with a higher detection probability than without the relevant adaptation.

When the driver selects a certain function of the vehicle, immediately an inference is made to the required tasks of the sensor and an appropriate adaptation of the sensor properties is brought about, e.g. the sensor is adapted completely to the short range if the assistance function “parking assistant” is selected.

- 5 On the other hand, if the vehicle is currently in a critical situation, then by adapting the sensor it is possible to increase the sensitivity in space regions/space cells that are deemed critical, thus in direction and/or distance in order to increase the detection quality of relevant targets.

The position of the vehicle, which may be queried e.g. via the navigation system, can be used for adapting the sensor properties. For this purpose, the information on the digital map may
10 already be divided into categories such as e.g. urban surroundings, country road, expressway and thereby allow for an appropriate configuration of the sensor. The information about these categories of the surroundings in which the vehicle is currently located allow for direct inferences to the sensor properties preferably to be set. For example, when driving on country roads, a range of below 100 meters is sufficient, while in city driving a range of about 50
15 meters may suffice. The information regarding the vehicle’s own movement may be used directly to adapt the required locating field of the sensor.

The installation location of the sensor on the vehicle is another parameter that allows for a suitable configuration. An installation on the side of the vehicle, for example, allows for the conclusion that only tasks of the short-range sensor system are to be performed.

- 20 By adapting the individual sensors it is possible to simplify or support the information processing in a central evaluation unit since this now only has to track a small number of targets. For example, when driving at low speed in an urban environment, the tracking of very distant targets may be omitted. This prevents the evaluation unit from being overloaded. Instead, the effort is minimized by adaptation to the relevant objects in the surroundings.

25 In order to be able to increase e.g. the distance resolution up to the centimeter range in the short range, the modulation of the emitted high-frequency signal itself is also designed to be adaptive in the adaptive radar sensor. In a sensor operating in accordance with the FMCW principle, the modulation amplitude itself, for example, is no longer set in a fixed manner, but is rather controlled or adapted dynamically, for example raised in order to increase the
30 distance resolution. To adapt the relative speed resolution, the length of certain frequency ramps is designed to be variable. Furthermore, the shape of the frequency ramps may be designed to be variable or adaptive as a function of certain required properties, e.g. graduated in a linear or in a nonlinear manner. Thus it is possible to utilize the resources of frequency and time, consequently the update rate, in an optimal and functionally adapted manner.

Furthermore, the required length of the Fourier transform, e.g. at 265, 512, 1024 or 2048 “bins”, may be adapted to the respective requirements.

The following variables may be used as parameter or information sources for controlled variables or input variables of an adaptation process of the sensor:

- 5 • the vehicle’s own speed;
- a detected target scenario;
for example, two preceding vehicles side-by-side; center lane free;
- a driver assistance function currently selected by the driver or automatically activated
by the vehicle such as e.g. a parking aid or an aid for starting from rest;
- 10 • critical situations or critical space regions;
the absolute position of the vehicle, which is provided via a vehicle navigation system;
- surroundings to be expected in the near future, e.g. an intersection, an exit or the like,
which is likewise provided via the vehicle navigation system or via a video sensor system,
and
- 15 • the installation location of the sensor on the vehicle.
- For performing the adaptation in the sensor, that is, for the actual implementation of
the setting of various parameters of the sensor, the following possibilities are used
individually or in combination:
- the adaptation of the speed resolution, for example, by increasing the resolution by an
20 adaptive elongation of a frequency ramp in the FMCW method, which increases the
observation time, or the increase of the sampling rate in a pulse radar;
- the adaptation of the distance resolution, for example, by increasing the resolution in
the short range by an increase of the frequency deviation in an FMCW radar or by a variation
of the pulse length in a pulse radar;
- 25 • the adaptation of the sampling rate in an analog/digital conversion within the radar
sensor or in additional evaluation units;
- an adaptation of the length of the fast Fourier transform (FFT) e.g. an increase in the
FMCW radar for improved detection in the short range of less than 1 meter;
- an adaptation of the integration time in a pulse radar as a function of the respectively
30 required update rate;

- an adaptation of the width or the shape of the antenna characteristic by switching the elements at a high-frequency level or by digital processing in the baseband, for example, by a digital beam shaping by complex-valued weighting of the baseband signals of individual antenna slots.

Abstract Of The Disclosure

In a radar sensor for a motor vehicle having a transmitting device and a receiving device, an adaptation of the sensor characteristic is achieved while a vehicle is operated in that transmitting parameters of the transmitting device and receiving parameters of the receiving device are variable.